

Supersonic Air Jets Preserve Tree Roots in Underground Pipeline Installation¹

Rob Gross² and Michelle Julene³

Abstract

Tree roots are often damaged during construction projects, particularly during trenching operations for pipeline installation. Although mechanical soil excavation using heavy equipment, such as an excavator or backhoe is considered the fastest the most economical method, it damages and destroys tree roots and can lead to unintentional tree loss, poor public relations, fines, and litigation. In sensitive areas around tree roots, soil excavation can be completed by hand although this is very slow and expensive. Alternate soil excavation methodologies are available, including a special technique that uses supersonic air streams to explode soil around non-porous items such as pipes, fiber optic cables, sewer and phone lines, and tree roots. This paper discusses the use of this technique for “high value” coast live oak trees (*Quercus agrifolia*) in urbanized areas. A case study is presented that discusses an appropriate application of the pneumatic soil excavation method. The pneumatic method is a valuable technique for root zone soil excavation. It preserves tree roots during construction to allow retention of the structural integrity of the root system and provides an opportunity to accurately understand actual root, soil, and tree conditions. This improves discussions with an affected tree owner, or other interested party, regarding future management options of the tree.

Introduction

Utilities of many types are routinely installed, repaired, and replaced underground. During soil excavation, tree and other plant roots are destroyed when conventional soil excavation methods are used. Conventional soil excavation methods utilize heavy machinery, such as excavators and backhoes that rip away plant roots as the construction trench is created. In terms of construction cost, conventional soil excavation is the least expensive method because it does not require special construction tools, equipment, training, or extra time. In terms of preserving trees, conventional soil excavation could be the most costly method because the ripping away of tree roots severely compromises tree health, often resulting in tree fatality.

Alternative soil excavation methods exist that preserve tree roots. These methods include manual, hydraulic, and pneumatic soil excavation methods. The manual soil excavation method utilizes hand tools, such as shovels, to remove soil from the root zone. The benefits of the manual soil excavation method include the use of inexpensive, common hand tools and minimal training. The drawbacks of this method include the length of time required to fully excavate the root zone, which could translate to a substantial increase in overall project costs. An additional

¹ An abbreviated version of this paper was presented at the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape, October 22-25, San Diego, California.

² Consulting Arborist, DendroTech, PO Box 766, Calistoga, CA 95616 (e-mail: grossfam@pacbell.net)

³ Environmental Specialist, Sonoma County Regional Parks Department, 2300 County Center Drive, #120A, Santa Rosa, CA 95403 (e-mail: mjulene@sonoma-county.org)

drawback to the manual soil excavation method is that, while large roots are preserved, they are scraped and smaller diameter roots are often broken. The manual soil excavation method is more appropriate to excavate small areas of soil.

In recent years, the hydraulic soil excavation technique has been refined (Gross 1995). The hydraulic soil excavation method utilizes water to remove soil from the root surface. The soil excavate is converted into a slurry. One application for using hydraulic excavation on oak roots is reported by Lindsey and others (Lindsey 1995). The primary benefit of the hydraulic soil excavation method is that the method is the most powerful, and therefore the fastest, of the alternative soil excavation methods. Hydraulic soil excavation can result in minimal observable impacts on living roots, and once excavated, the roots can be inspected if desired. There are several drawbacks to this soil excavation method, such as available water supply, specialized equipment, training, and the slurry itself. Specialty equipment, including hose and nozzles to implement the excavation process as well as vacuum pumps to clean-up the slurry, can be expensive. Training is required to operate the equipment and to understand the appropriate water pressure application rate to specific ground and root conditions. The slurry itself presents several concerns. The excavated soil, when mixed together with the water in the excavation process, can increase the waste volume up to ten fold. This slurry cannot be used as trench backfill and therefore must be removed from the site. Slurry removal requires additional equipment and can result in additional disposal costs if landfill disposal is necessary. Because the slurry cannot be used as trench backfill, new soil must be imported, often at additional cost. The slurry also creates a potential slip and fall hazard at the excavation site and the moistened soils along the trench walls are more likely to cave in than are dry soils. The hydraulic soil excavation method is recommended for high volume excavations, in which trench depth and clean up are not issues.

The pneumatic soil excavation method forces rapidly moving air into the soil pores until they fail in a series of small explosions away from non-porous objects, such as underground utilities and plant roots. The excavated soil is transformed into crumbs that are relocated. The primary benefit of the pneumatic soil excavation method is that it protects tree roots, including small diameter and fine roots. Additional benefits of the pneumatic soil excavation method include unlimited air supply, relatively minimal clean-up, and re-usability of the excavate. Another benefit of the pneumatic soil excavation method is that it can be used along with conventional machinery after the root zone is excavated of soil. First, the soil among the roots is excavated using the pneumatic method. Then, a conventional excavator or backhoe can be used below the root level to increase trench depth at an increased production rate, while avoiding root damage. Combined, this hybrid process is particularly efficient. This allows trench construction, particularly for deep trenches, to proceed at a more efficient rate of speed. Drawbacks of the pneumatic soil excavation method include the need for special equipment and training. In addition to the specialized nature of the tools, they can overheat while in use and high ambient temperatures reduce excavation efficiency. The pneumatic soil excavation method is recommended for high value trees, in settings where a trench must be dug below three feet deep, and when considerations such as clean-up, safety, and construction production time exist.

The subject case study involved a construction trench for an underground utility installation in a residential area. The community of Mirabel Heights in Sonoma County, California originally was developed as a summertime vacation community in

the 1940s. By the 1980s, it had converted to fully residential and over 70 percent of the septic systems were failing. Small septic tanks were placed on small, hilly lots. Streets were paved in the 1960s and a water distribution system was installed in subsequent years. The sewer installation project cost approximately \$4 million for approximately 200 homes. Project planning, environmental compliance, and approval took more than 10 years to complete. This project included installation of a sewer transmission pipeline in a residential area. The trenches would be two feet wide and would exceed a ten-foot depth in some places. Due to extremely narrow roads, the construction trench would begin within three feet of the trunk of the subject tree (Sonoma County Water Agency 1999).

In this case study, the subject coast live oak tree (*Quercus agrifolia*) was considered to be of high value by the property owner. The property owner stressed that the tree increased his property value, adding up to \$50,000 to his property value, although a valuation report was not produced. The property owner demonstrated a considerable attachment to the tree, and admitted to spending large sums of money to an Arborist throughout the years for tree care. The property owner requested that the pipeline alignment be relocated to minimize or avoid impacts to the tree. The property owner suggested that the pipeline be moved onto private property across the street from the tree, and if that were not possible, then to move the pipeline an additional two to three feet from the design location.

The property owner had contacted his Arborist and Attorney in case the tree fell or died due to the construction, and communicated these actions verbally and in writing to the Agency. The property owner also threatened to litigate if the tree was damaged or lost due to the construction project. The Agency's Environmental Specialist and Consulting Arborist were brought in to document the overall condition of the tree, assess potential impacts of the Project on the tree, and develop recommendations to reduce potential impacts. The property owner agreed to this consultation. The initial assessment of the tree revealed that the tree was large sized, in poor health, was structurally compromised, had received poor quality arboricultural care, and was severely impacted by landscape surroundings.

The tree's canopy extended across the street and onto private property across the street. Lesions were observed on the low trunk bark near the soil line, suggesting that a root rot was involved. Armillaria root disease was observed at the root collar and into the sapwood. This was determined visually after removing portions of the bark. The trunk base was hollow at ground level and also at approximately twelve feet from the base. A cement-filled cavity was located at six feet from the base. The tree had been topped repeatedly. There were no lower limbs. Two large limbs were cabled together using ½-inch diameter wire rope, which was wrapped around these limbs and girdled them. Foliage was thin, with leaves on only 40 percent of the potential canopy. Poor arboricultural procedures had resulted in an uncommonly weak structure and contorted tree shape. The presence of Armillaria root disease also indicated poor tree health, as this species of oak is usually immune to highly resistant to this fungus (Raabe 1979).

Site conditions surrounding the tree not only contributed to the tree's overall condition, but also limited placement of the construction trench. The tree was located adjacent to and above the property owner's driveway on a small lot. The paved public road surface began within one foot of the base of the tree trunk. Existing utilities were located in the paved public road. Surrounding soil surface was compacted due to previous construction and heavy, on-going use surrounding the tree including the

property owner's garage and driveway. Even though the tree was in poor health and unfavorable site conditions were present, the pneumatic soil excavation method was recommended to improve public relations and avoid potential litigation. In this case study, it was necessary to conduct careful soil excavation and trench construction to demonstrate significant effort to the property owner towards minimization of tree impacts. The conventional method would have destroyed tree roots, possibly resulting in tree fatality and litigation. The manual method would have been too slow and the hydraulic method would not have been appropriate for this application, due to the depth of the construction trench.

Methods

In the subject case study, the pneumatic soil excavation method was conducted using an Air Knife, model XL 150/90, to explode soil around tree roots. A rushing air stream, accelerated to twice the speed of sound (Mach 2), was focused in the root zone and filled soil pores. The rapidly building air pressure created a series of small explosions. As the soil exploded, it was forced away from the tree roots and was transformed into small crumbs. The pneumatic soil excavation method was conducted only within the top three feet of soil because ninety percent of most tree roots were located in this space. After the soil was excavated, the preserved root system created a "tree root bridge" free of soil, beneath which conventional mechanical soil excavation was employed to achieve the required trench depth. Skilled combination of pneumatic soil excavation in tandem with the excavator or backhoe beneath the tree root bridge maintained construction production and root integrity.

Results

With the use of the "root friendly," pneumatic soil excavation technique, soil was successfully removed from the tree root area and tree conditions were observed. This soil excavation technique allowed retention of the tree root bridge, a depth of approximately three feet below the soil surface. Beneath the tree root bridge conventional trench excavation utilizing a backhoe was completed to achieve a trench depth of approximately ten feet. In addition to the successful excavation of soil in the root area and completion of trench excavation, pneumatic soil excavation permitted the discovery of poor tree health and poor structural integrity. Because the roots were not damaged during soil excavation, the property owner was able to visually inspect the tree roots and the Agency's Environmental Specialist and Consulting Arborist were able to discuss the tree's condition and alternatives with the property owner. Soil removal within the root zone led to the discovery of the following:

1. Prior installation of an underground water pipe resulted in cutting the tree's roots approximately 14 feet north of the tree trunk and road construction, which occurred within one foot of the tree trunk, also severed tree roots.
2. The roots in the excavated trench were three to four inches diameter and the soil surrounding them was compacted. No white roots were observed. This suggested anaerobic conditions or a rootlet disease. *Phytophthora* root rot is one disease that commonly kills rootlets. Rootlet loss weakens trees and would partially explain why this tree contracted *Armillaria* root disease.

3. The excavated trench exhibited no healthy roots. Numerous voids observed in the trench faces indicated where roots had previously been, but had long since decayed. Some roots suffered from advanced decay indicated by a watery soft consistency. Most of these roots exhibited dead bark, white fungal mycelium at the cambium, and white rotted wood, which indicated a pathogenic colonization (Baumgartener and Rizzo 2001b). The roots and part of the lower trunk were being attacked by *Armillaria* root disease, which is widely distributed in most regions of California dominated by development, such as the San Francisco Bay Area (Baumgartner and Rizzo 2001a).
4. No healthy roots were cut in the pneumatic soil excavation process.
5. The opportunity to discover actual soil and root conditions allowed the tree owner to see and understand that the tree was compromised prior to construction.

Discussion

In this case study, the Agency's Environmental Specialist and Consulting Arborist were presented with a difficult challenge. A necessary underground utility was being installed in a residential neighborhood with very narrow streets. A property owner, who had an oak tree on his property, threatened litigation if the construction project adversely impacted his tree. Visual inspection of the tree indicated that the specimen suffered from numerous and severe health and structural problems as well as a compromised growing environment. Nonetheless, the Agency's Environmental Specialist and Consulting Arborist were challenged to recommend and perform a soil excavation method that would minimize potential tree impacts without resulting in significant construction production delays.

Three primary issues were considered in deciding which soil excavation method would be most appropriate. These issues included tree preservation, minimal delay in construction, and relative overall cost. The conventional soil excavation method was eliminated as an option because the tree roots would have been destroyed thereby resulting in substantial tree impacts. The cost of the potential litigation and poor public relations, as well as future potential tree removal costs, would have significantly increased the overall cost of the project. The manual soil excavation method was eliminated as an option because it would have slowed construction production to an unacceptable level, which also would have significantly increased the overall cost of the project.

The hydraulic and pneumatic soil excavation methods were considered as possibly appropriate. Rizzo and Gross (2000) compare hydraulic and pneumatic techniques. Harris and others (1999) discuss hydraulic and pneumatic for locating roots. Both methods would have preserved the tree roots, would have resulted in minimal delay in construction production, and would have similar relative overall cost. The hydraulic soil excavation method was determined to be inappropriate in this case due to the necessary trench depth. The moistened soil would have rendered the construction trench more subject to failure at the necessary depth. The pneumatic soil excavation method was determined to be the most appropriate method within the root zone of the subject case study.

The pneumatic soil excavation in combination with conventional methods using a backhoe was particularly effective and met the objectives of the task. The tree roots

were preserved thereby minimizing tree impacts, construction production was maintained, and the additional cost of excavating the soil carefully was minor when compared to the cost of potential litigation. The pneumatic soil excavation technique is recommended for “high value” trees, whatever the criteria. In our example, the Mirabel Heights tree was considered to be a high value tree by the property owner even though the specimen was in poor health.

In the subject case study, the pneumatic soil excavation technique allowed us to observe *Armillaria* root disease and other root system limitations. Because the pneumatic soil excavation preserved the tree roots, including those affected by *Armillaria* root disease, we were able to discuss the condition of the tree with the property owner, improving communication regarding future management of the tree. Pneumatic soil excavation is a valuable technique for root zone soil excavation, as it preserves tree roots during construction to allow retention of the structural integrity of the root system, and provides an opportunity to accurately understand actual tree conditions, thereby improving communication.

References

- Baumgartener, Kendra; Rizzo, David M. 2001a. **Distribution of *Armillaria* ssp. in California.** *Mycologia* 93(5) 821-830.
- Baumgartener, Kendra; Rizzo, David M. 2001b. **Ecology of *Armillaria* ssp. in mixed—hardwood forests of California.** *Plant Disease* (September 2001); 947-951.
- Gross, Rob. 1995. **Construction application of hydraulic soil excavation.** In: Watson, G.; Weeley, D., editors. *Proceedings: trees and building sites*. Savoy, IL: International Society of Arboricultural; 177-184.
- Harris, R. W.; Clark, J. R.; Matheny, N. P. 1999. **Arboricultural: integrated management of landscape trees, shrubs, and vines.** 3rd Edition. Prentice Hall.
- Lindsey, P. A.; Gross, Rob; Milano, R. 1995. **An investigation to assess the import of street infrastructure improvement on roots of adjacent cork oak tree.** In: Watson, G.; Neeley, D. *Proceedings: trees and building sites*. Savoy, IL: International Society of Arboricultural; 22-32.
- Raabe, R. D. 1979. **Resistance or susceptibility of certain plants to *Armillaria* root rot.** University of California. Agri. Science Leaflet #2591.
- Rizzo, David M.; Gross, Rob. 2000. **Distribution of *Armillaria* on pear root systems and a comparison of root excavation techniques.** In: Stokes, Alexia, editor. *Proceedings: The supporting roots of trees and woody plants: form, function, and physiology*. Kluwer Academic Press; 305-311.
- Sonoma County Water Agency. 1999. **Mirabel Heights water pollution control project contract drawings and specifications.**